Journal of Physics: Conference Series **85** (2007) 012031 doi:10.1088/1742-6596/85/1/012031

The preliminary investigation of imaging photoplethysmographic system

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Abstract. A preliminary CCD camera-based imaging photoplethysmographic (PPG) system is described to detect the blood perfusion in tissue. Attention of imaging photoplethysmography (PPG) is drawn to the potential applications in visualised blood perfusion. The introduction of the fast digital camera inspires the development of imaging PPG which allows the ideally contactless monitoring with larger field of view and different depth of tissue by applying multi-wavelength LEDs. The CCD camera-based spectral imaging PPG system in both transmission mode and reflection mode is constructed to validate the feasibility of this technique. The PPG signal can be derived in both transmission mode and reflection mode, which is obviously different from multi-wavelength LEDs or monitoring at various regions of tissue. The investigation for the system functionality leads to the further development of imaging PPG system and the engineering model for 3-D visualised blood perfusion of tissue.

1. Introduction

Photoplethysmography (PPG) is a non-invasive optical technique for detecting blood volume changes in tissues [1]. The fundamental modus-operandi of PPG technology is the optical detection of the dynamic cardiovascular pulse-wave, generated by the heart, as it travels throughout the body. Pulse waves obtained from the PPG signal can deliver clinically valuable information about tissue blood perfusion.

The principle of PPG, first used by Hertzman, is simple, which employs a small light source and a photosensitive detector (photoelectric cell) applied to the skin. The emitted light is scattered in the tissue and partly absorbed. Part of the scattered light emerges again through the skin and is detected by the photoelectric cell, which can be placed either beside or opposite the light source (reflection and transmission mode [3], respectively). The intensity of the light detected by reflection or transmission is converted to the PPG signal. Thus the conventional PPG system is focus on the single spot measurement. With the introduction of the fast digital camera into the clinical imaging monitoring and diagnosis system, the emphasis of photographic method is shifting to photonic methods that use tomography principles to non-invasive image optical contrast at depths of several millimetres to centimetres with high sensitivity [4], which inspires developing the conventional PPG technology to imaging PPG, which replaces the photodiode with the camera. Imaging PPG allows monitoring with larger field of view, so as to improve the ability to probe biologic interactions dynamically and to study disease over time.

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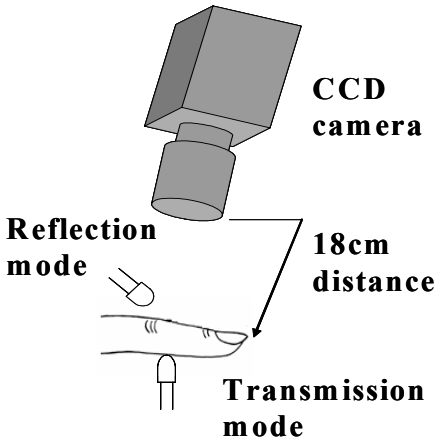
In this paper, a CCD camera-based PPG system is presented that is capable of monitoring blood perfusion based on both transmission mode and reflection mode without making contact with the tissue. The study is aim at developing and testing of the new experimental technique for detection of PPG signals at any selected wavelength.

2. Methodology

A. Hardware

The reflection and transmission mode PPG imaging system is depicted in Fig. 1. A subject's finger is illuminated by light-emitting diodes producing light centered at selected wavelengths of 660 nm, 840 nm and 905nm. A Hitachi KP-M1 monochromatic 2/3'' CCD USB camera is located 20 cm above the finger. The light intensity varies with the pulsing of the blood. A plot for this variation against time is referred to be a photoplethysmographic (PPG) signal. A frame rate of 30 frames per second provides an appropriate tradeoff between sampling often enough to capture the fine structure of the PPG signals and allowing the camera sufficient time to integrate and read out each frame. When the test starts, the camera writes the captured frames to a PC as an uncompressed AVI file.

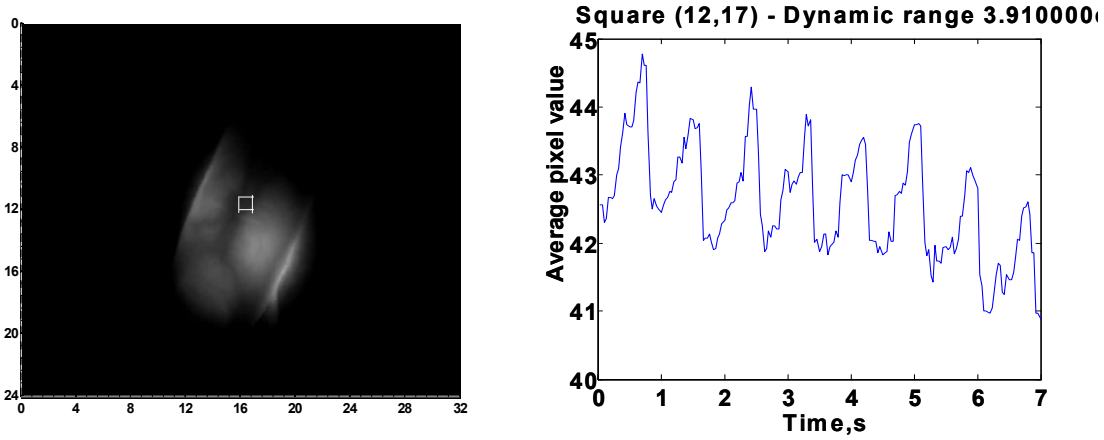
Fig. 1 Imaging PPG system.



B. Signal Acquisition

The resulting AVI file from the camera is processed by Matlab (The Math Work Inc. USA). Each frame from AVI files is divided into boxes or groups of adjacent pixels. For each frame the average pixel value of each box is calculated. Plotting the average pixel value of each box for each frame against the time yields a PPG signal. This process is illustrated in Fig. 2. The variations in the pixel values in each frame are influenced by both the changes in absorption by the finger as the blood pulses through it and change in the ambient light, to which the camera is also sensitive. Although the camera is more susceptible to interference from ambient light than a conventional contact probe, the PPG signals captured by the camera have been shown to be comparable to those captured by conventional probe.

Fig. 2 (A) A sample frame with a 20x20 pixel box outlined. (B) The change in the average pixel value of that box over time.

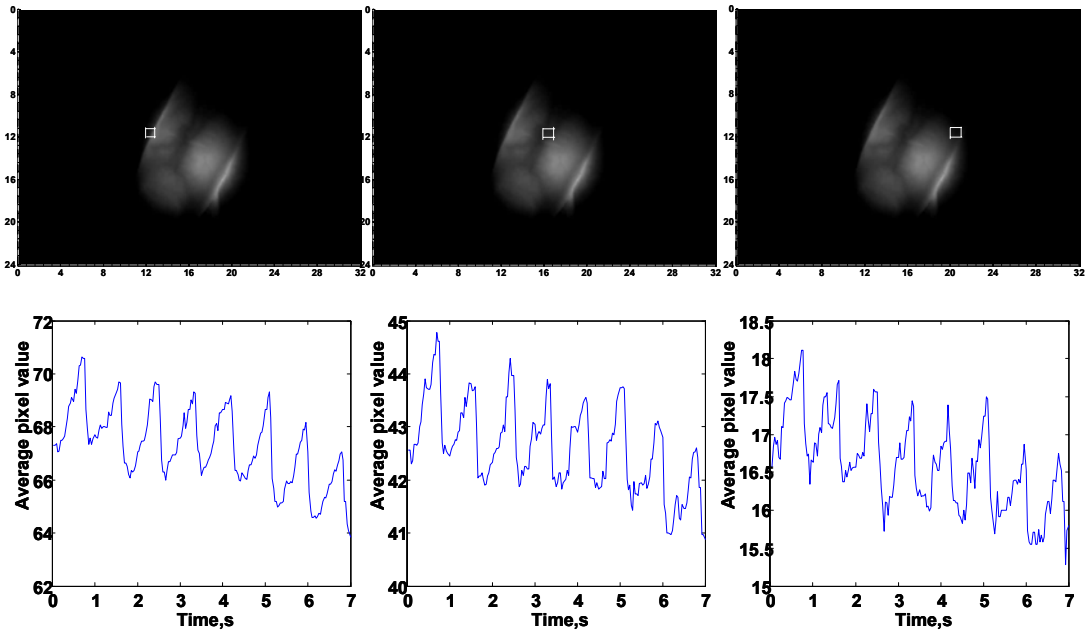


3. Results and discussions

A. Transmission mode

Fig. 3 depicts typical results obtained from the camera-based PPG transmission system. For the LED of 905nm wavelength, the PPG signal can be derived with larger field of view at the same time, and for different measurement regions, the PPG signals are obviously different in both shape and amplitude, which can be concluded that the signals are contributed from different area containing different tissue components.

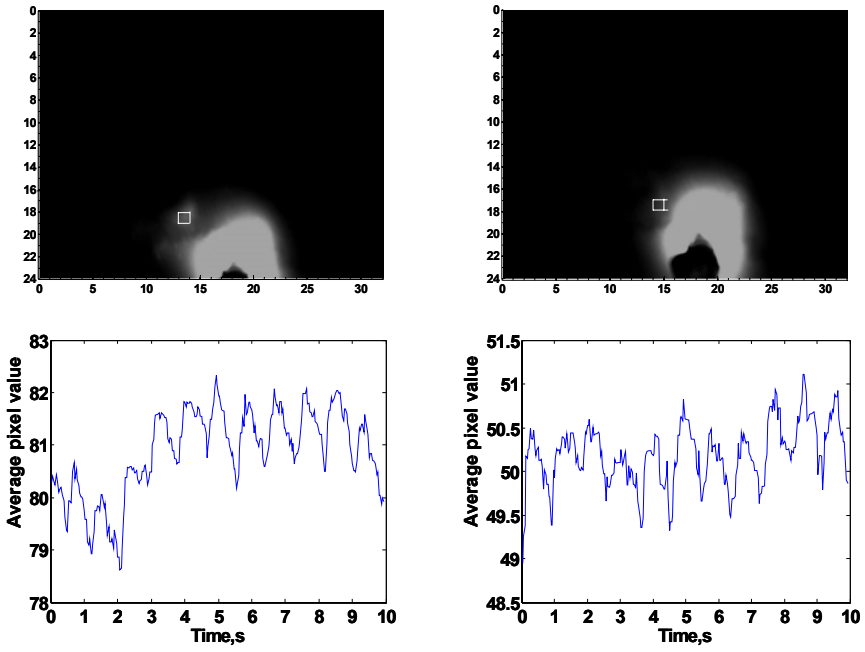
Fig.3 Transmission mode illuminated by the 905nm LED



B. Reflection mode

Fig. 4 depicts the results from the imaging PPG reflection system, illuminated by LED with wavelength of 660nm and 840 nm. The signals from the same measurement area are different from different wavelength LEDs, which can be explained as the penetration depths of different wavelength LED are different, and thus the two LEDs illuminate two different vascular beds [2].

Fig. 4 Reflection mode illuminated by the 660nm and 840nm LED



4. Conclusions

The newly developed imaging PPG system has been implemented and tested. The PPG signals can be obtained from the camera-based system. The resulting signals demonstrated the feasibility of this technique, which might be useful for the studies and assessment of large field measurement of various segment blood perfusion in skin.

5. Acknowledgement

The authors are grateful to our eternal supervisor Professor Peter Smith, and would like to thank all the members in the Photonics Engineering and Health Technology Research Group of Loughborough University for their enthusiastic help.

6. Reference

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